

Development of Electrode Architectures for High Energy Density Electrochemical Capacitors

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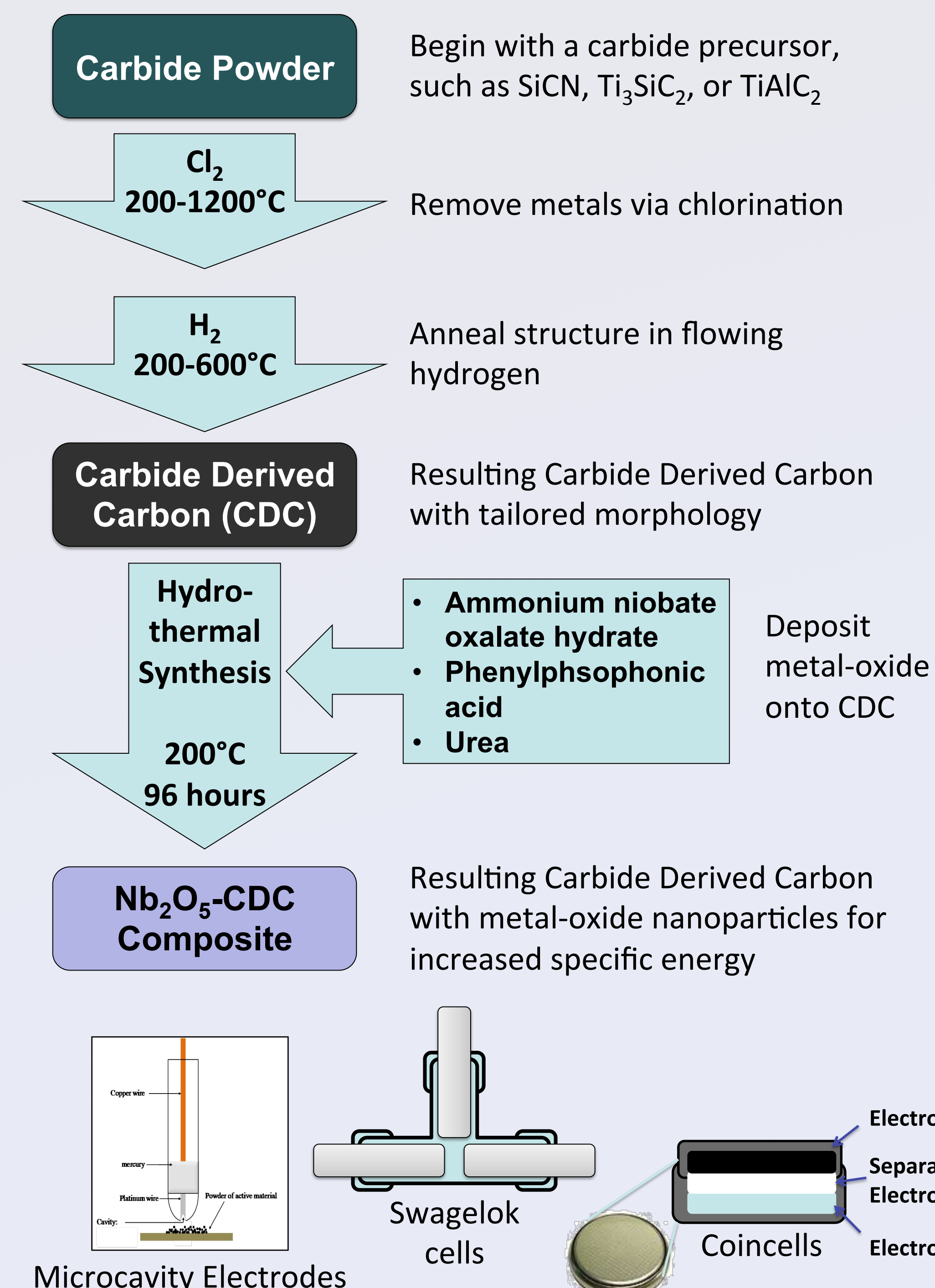
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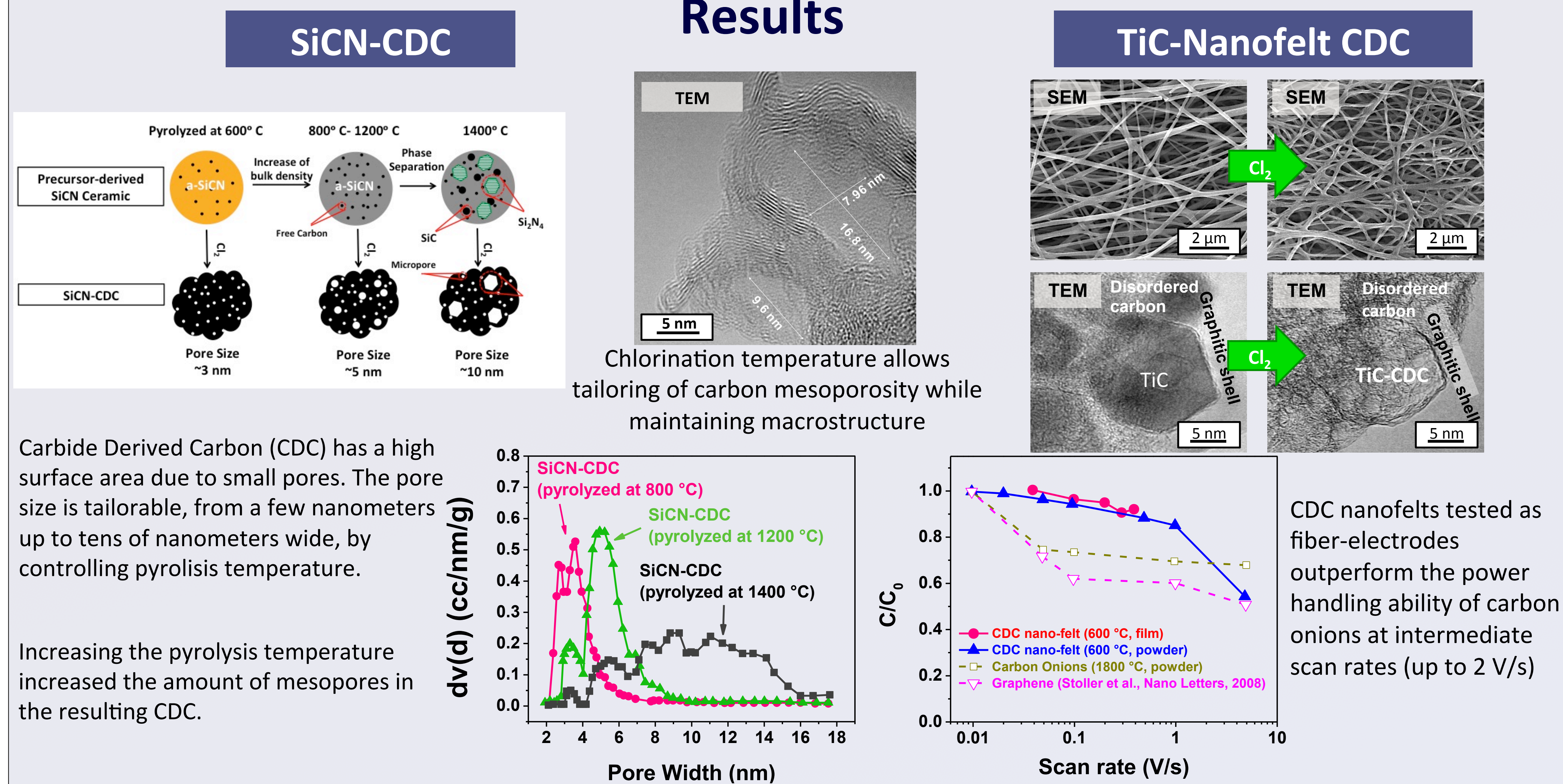
Introduction

The principal goal of the present research is to create an electrode architecture for electrochemical capacitors (ECs) that possesses both the high specific power of carbon supercapacitors and the high specific energy of pseudocapacitive materials. The design and fabrication of these electrodes are based on the nanoscale deposition of transition metal oxides onto mesoporous carbon-based supports. Extraction of metals from carbides can generate a broad range of carbon nanostructures, which are known as Carbide-Derived Carbons (CDCs). The structures of CDCs as well as their pore size distribution depend on the crystal structure of the carbide precursor as well as process parameters including temperature, time and environment. Nanoscale transition metal oxides such as niobium oxide (Nb_2O_5) can be easily synthesized on the CDC surface via an aqueous hydrothermal route. The oxide size can be tailored to match the CDC porosity, allowing for optimization of ionic and electronic transport within the electrode. A key feature with these architectures is that each component possesses interconnected mesoporosity to facilitate electrolyte access to both phases.

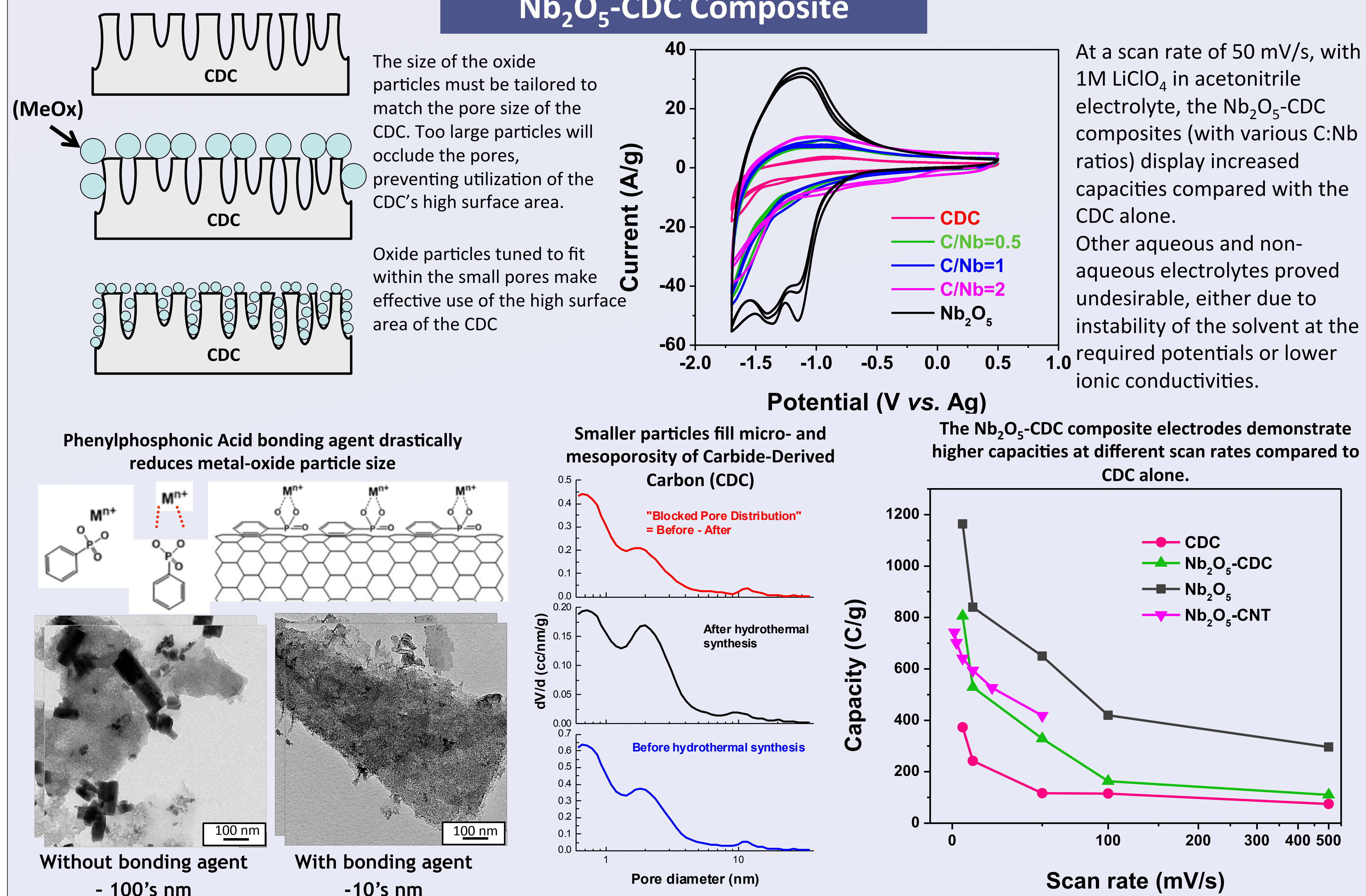
Experimental



Results



Nb_2O_5 -CDC Composite



Conclusions

- CDC with hierarchical pore structure (micropores & mesopores with mean pore size, 3–10 nm) and large BET surface area, up to 2400 $\text{m}^2 \text{g}^{-1}$, were synthesized by etching amorphous or crystalline polymer-derived SiCN ceramics.
- Micropores form by etching Si atoms from the SiC phase, while mesopores derive from the elimination of Si–N moieties. The resulting morphology (pore size, PSD, and SSA) strongly depends on pyrolysis temperature of the preceramic polymer, as well as on etching conditions.
- Mechanically flexible TiC-CDC nano-felts were developed through chlorination of electrospun TiC nano-fibrous felts. The TiC-CDC nano-felts retained the morphological properties of the precursor, while had substantially higher values of SSA and pore volume.
- Nanoscale Nb_2O_5 can be easily synthesized within the pores of CDC support.
- Capacitance measurements for the Nb_2O_5 -CDC material shows a high level of energy storage, significantly higher than CDC.

Future Work

- Scale up production of Nb_2O_5 -CDC composite powder
- Incorporate powder into coin cell devices
- Optimize coin cell electrode loading and morphology for enhanced specific energy and power

Acknowledgements

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References

- S.-H. Yeon, P. Reddington, Y. Gogotsi, J. E. Fischer, C. Vakifahmetoglu and P. Colombo, *Carbon*, 2010, 48, 201-210
- V. Presser, L. Zhang, J. J. Niu, J. McDonough, C. Perez, H. Fong and Y. Gogotsi, *Advanced Energy Materials*, 2011, 1, 423-430
- Y. Gao, V. Presser, L. Zhang, J. J. Niu, J. K. McDonough, C. R. Pérez, H. Lin, H. Fong and Y. Gogotsi, *Journal of Power Sources*, 2012, 201, 368-375
- V. Presser, M. Heon and Y. Gogotsi, *Advanced Functional Materials*, 2011, 21, 810-833
- X. Wang, G. Li, Z. Chen, V. Augustyn, X. Ma, G. Wang, B. Dunn and Y. Lu, *Advanced Energy Materials*, 2011, 1, 1089-1093
- J. W. Kim, V. Augustyn and B. Dunn, *Advanced Energy Materials*, 2012, 2, 141-148
- Y. Zhao, J. Li, C. Wu and L. Guan, *Nanoscale Res Lett*, 2011, 6, 71